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Liquid Biofuels: The Next Generation

The many subscribers to Nexant's landmark Q42006 report, "Liquid Biofuels: Substituting for Petroleum" include the world's leading national and multinational oil and gas companies, chemical and agricultural giants, seed biotech developers, biofuels producers, government and enzyme environmental and energy agencies, and entrepreneurs. Since its publication, however, the technical, industrial, and commercial framework has dramatically changed in many ways. Global crude oil prices spiked to \$147 per barrel in July, 2008, then dropped to one third of this by year's end. Despite the current lows, many believe that higher energy prices will reemerge when global economies recover, opening new opportunities and challenges for global biofuels. "Food versus fuel" conflicts and fitting biofuels into the enormous current fuel distribution and vehicle infrastructure will particularly challenge these stakeholders. Needed are biofuels that blend well with conventional liquid fuels or are "drop in" substitutes for them. Such technical challenges and commercial limitations have driven investments in new feedstocks and production technology. Biomass is potentially the world's largest, most sustainable energy resource (i.e., with less use of fertilizers, ag chemicals, irrigation, or valuable farmland). Only some new options will succeed in finding an economic role to play within the overall energy balance.

This new Nexant *ChemSystems* study provides a timely assessment of the leading edge biofuels products and technologies available, and updates the status of conventional fermentation ethanol and ester-based biodiesel technology, regulations, and businesses. Existing and new options are evaluated from technical, economic, and commercial perspectives, including examining competitive routes, cost of production compared to petroleum products, sensitivities to cost factors and use of new feedstocks, and developmental and market players. Sustainability, and government policy roadmaps, is considered. Technology, market, and policy views include North America, Latin America, Europe, Asia, and Africa.

This study should be of interest to companies considering market entry or expansion, acquisitions, partnering, or offering goods or services to the emerging biofuels sector, as well as to other stakeholder organizations.

REPORT OVERVIEW

These feedstocks, liquid biofuels, routes/strategies, and players are included in the study:

- New feeds, including **sorghum** and **cassava** for fermentation and **jatropha** and **microalgae** for biodiesel
- Biomass gasification to syngas for catalytic conversion to renewable diesel (BTL), higher alcohols, or fermentation of CO in syngas to ethanol (Coskata)
- Biomass wastes, energy cane, and switchgrass crops converted to fermentable sugars
- Catalytic conversion of bioethanol to gasoline hydrocarbons or higher alcohols
- Adaptation of corn or sugar fermentation ethanol facilities to butanol production
- Synthetic biology applied to existing or new microbes to produce hydrocarbons by fermentation of sugars (Amyris, LS9)
- Renewable diesel made by hydrocracking (Neste Oil, Petrobras) or FCC conversion (Petrobras) of fats and oils in refineries
- Technologies using more novel approaches, including: sugars to hydrocarbons by Aqueous Phase Reforming (Virent), alcohols via organic acids by hydrogenation (Terrabon and Zeachem), photosynthetic algae making ethanol (Algenol), algae (non-photosynthetic) making lipids by sugar fermentation (Solazyme)
- **Bio-oil and bio-char** via pyrolysis, with oil upgrading, and char burial as a carbon offset / soil amendment strategy
- Biorefineries producing fuels, power and chemicals from biomass feedstocks, utilizing the value of different components in the biomass feedstocks and intermediates



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